Examiner's Amendment

* An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

The following is a final version of the claims:

1. A method for increasing an error tolerance of an array of m storage units in which m is an integer, comprising:

storing k stripes across the array of m storage units in which k is an integer, each stripe comprising n + r elements in which n is the number of data elements in the stripe and r is the number of redundant elements in the stripe, m > n + r, jm = k(n + r), and j is an integer , each stripe forming a correcting code, the correcting code being one of an erasure correcting code having a minimum Hamming distance d and an error correcting code having a minimum Hamming distance d, and each respective element of a stripe being stored on a different storage unit;

selecting an element in a donor stripe when a difference between a minimum distance of the donor stripe and a minimum distance of a recipient stripe of the k stripes is greater or equal to 2 and when an element of the recipient stripe has been lost, the donor stripe and the recipient stripe being from the k stripes, the selected element being stored on a storage unit comprising no elements of the recipient stripe; and

increasing the minimum distance of the recipient stripe by rebuilding the lost element of the recipient stripe on the selected element of the donor stripe so that the recipient stripe can tolerate a loss of another element without loss of data.

2. The method according to claim 1, wherein the minimum Hammindistance of the recipient stripe is d > 2 before selecting the element in the donor stripe.

3. The method according to claim 1, further comprising indicating to the storage units storing the donor stripe that the selected element has been donated before rebuilding the lost element of the recipient stripe on the selected element.

4. (canceled)

5. The method according to claim 1, wherein the storage units comprise hard disk drives.

6. The method according to claim 1, wherein the storage units comprise RAM storage devices.

7. The method according to claim 1, wherein the donor stripe is further selected based on a minimal performance impact on the array.

8. The method according to claim 1, further comprising selecting the recipient information based on an improved performance of the array.

9. The method according to claim 1, wherein the correcting code comprises a parity code.

10. The method according to claim 1, wherein the correcting code comprises a Winograd code.

11. The method according to claim 1, wherein the correcting code comprises a symmetric code.

12. The method according to claim 1, wherein the correcting code comprises a Reed-Solomon code.

13. The method according to claim 1, wherein the correcting code comprises an EVENODD code.

14. The method according to claim 1, wherein the correcting code comprises a derivative of an EVENODD code.

15. The method according to claim 1, wherein the array comprises redundancy based on a product of a plurality of correcting codes.

16. The method according to claim 15, wherein at least one of the correcting codes comprises a parity code.

17. The method according to claim 15, wherein at least one of the correcting codes comprises a Winograd code.

18. The method according to claim 15, wherein at least one of the correcting codes comprises a symmetric code.

19. The method according to claim 15, wherein at least one of the correcting codes comprises a Reed-Solomon code.

20. The method according to claim 15, wherein at least one of the correcting codes comprises an EVENODD code.

21. The method according to claim 15, wherein at least one of the correcting codes comprises a derivative of an EVENODD code.

22. The method according to claim 1, wherein when an element in the donor stripe fails during rebuilding at least a portion of recipient information from the recipient stripe on the selected element, the method further comprising:

terminating rebuilding at least a portion of recipient information from the recipient stripe on the selected element;

selecting a second donor stripe from the plurality of stripes when a difference between a minimum distance of the second donor stripe and a minimum distance of the second recipient stripe is greater or equal to 2;

selecting a donor element in the second donor stripe; and

rebuilding at least a portion of lost recipient information from the recipient stripe on the selected element in the second donor stripe.

23. The method according to claim 1, wherein when a spare element becomes available, the method further comprising assigning the spare element to a selected storage unit.

24. A method of increasing the failure tolerance of an array of m storage units that is vulnerable to selected patterns of failures, comprising:

storing k stripes across the array of m storage units, each stripe comprising $n + r$ elements in which n is the number of data elements in the strip and r is the number of redundant elements in the stripe, $m > n + r$, $jm = k(n + r)$, and j and k are integer, each stripe forming an erasure or error correcting code having a minimum Hamming distance d, and each respective element of a stripe being stored on a different storage unit;

subsequent to an element failure, selecting a recipient element;

selecting an element in a donor stripe **wherein** a failure tolerance of the array is increased following a rebuild operation; and

rebuilding a lost element of the recipient stripe on the selected element of the donor stripe.

25. The method according to claim 24, wherein the minimum Hamming distance of the recipient stripe is $d > 2$ before selecting the element in the donor stripe.

26. The method according to claim 24, wherein the minimum Hamming distance of the array is increased upon completion of rebuilding so that the recipient stripe can tolerate a loss of another element without loss of data.

27. The method according to claim 24, wherein the recipient element is selected based on a failure pattern of the array.

28. The method according to claim 24, wherein the donor element is selected based on a predetermined target pattern.

29. The method according to claim 24, further comprising indicating to the storage units storing the donor stripe that the selected element has been donated before rebuilding the lost element of the recipient stripe on the selected element.

30. (canceled)

31. The method according to claim 24, wherein the storage units comprise hard disk drives.

32. The method according to claim 24, wherein the storage units comprise RAM storage devices.

33. The method according to claim 24, wherein the erasure or error correcting code comprises a parity code.

34. The method according to claim 24, wherein the erasure or error correcting code comprises a Winograd code.

35. The method according to claim 24, wherein the erasure or error correcting code comprises a symmetric code.

36. The method according to claim 24, wherein the erasure or error correcting code comprises a Reed-Solomon code.

37. The method according to claim 24, wherein the erasure or error correcting code comprises an EVENODD code.

38. The method according to claim 24, wherein the erasure or error correcting code comprises a derivative of an EVENODD code.

39. The method according to claim 24, wherein the array of storage units comprises redundancy based on a product of a plurality of erasure or error correcting codes.

40. The method according to claim 39, wherein at least one of the erasure or error correcting codes comprises a parity code.

41. The method according to claim 39, wherein at least one of the erasure or error correcting codes comprises a Winograd code.

42. The method according to claim 39, wherein at least one of the erasure or error correcting code comprises a symmetric code.

43. The method according to claim 39, wherein at least one of the erasure or error correcting code comprises a Reed-Solomon code.

44. The method according to claim 39, wherein at least one of the erasure or error correcting code comprises an EVENODD code.

45. The method according to claim 39, wherein at least one of the erasure or error correcting code comprises a derivative of an EVENODD code.

46. A method for increasing an error tolerance of a storage system comprising a plurality of arrays of storage units, each array comprising m storage units in which m is an integer, the method comprising:

storing k stripes across each respective array of m storage units in which k is an integer, each stripe comprising n + r elements in which n is the number of data elements in the stripe and r is the number of redundant elements in the stripe, m > n + r, jm = k(n + r), and j is an integer, each stripe forming a correcting code, the correcting code being one of an error correcting code having a minimum Hamming distance d and an erasure correcting code having a minimum Hamming distance d, and each respective element of a stripe being stored on a different storage unit in the array;

selecting an element in a donor stripe when a difference between a minimum distance of the donor stripe and a minimum distance of a recipient stripe is greater or equal to 2 and when an element of the recipient stripe is lost, the donor stripe and the recipient stripe being from the k stripes, the selected element being stored on a storage unit having no elements of the recipient stripe; and

increasing the minimum distance of the recipient stripe by rebuilding the lost element of the recipient stripe on the selected element of the donor stripe so that the recipient stripe can tolerate a loss of another element without loss of data.

47. The method according to claim 46, wherein the donor stripe is stored on an array that is different from the array of the recipient stripe.

48. The method according to claim 46, wherein the donor stripe is stored on the same array as the recipient stripe.

49. The method according to claim 46, wherein the minimum Hamming distance of the recipient stripe is d > 2 before selecting the element in the donor stripe.

50. The method according to claim 46, further comprising indicating to the storage units storing the donor stripe that the selected element has been donated before rebuilding the lost element of the recipient stripe on the selected element.

51. (canceled)

52. The method according to claim 46, wherein the storage units comprise hard disk drives.

53. The method according to claim 46, wherein the storage units comprise RAM storage devices.

54. The method according to claim 46, wherein the selected element of the donor stripe is further selected based on a minimal performance impact on the donor stripe.

55. The method according to claim 46, wherein the donor stripe is further selected based on a minimal performance impact on the storage system.

56. The method according to claim 46, further comprising selecting the recipient information based on an improved performance of the recipient stripe.

57. The method according to claim 46, further comprising selecting the recipient information based on an improved performance of the storage system.

58. The method according to claim 46, wherein correcting code comprises a parity code.

59. The method according to claim 46, wherein correcting code comprises a Winograd code.

60. The method according to claim 46, wherein correcting code comprises a symmetric code.

61. The method according to claim 46, wherein correcting code comprises a Reed-Solomon code.

62. The method according to claim 46, wherein correcting code comprises an EVENODD code.

63. The method according to claim 46, wherein correcting code comprises a derivative of an EVENODD code.

64. The method according to claim 46, wherein the array comprises redundancy based on a product of a plurality of correcting codes.

65. The method according to claim 64, wherein at least one of the correcting codes comprises a parity code.

66. The method according to claim 64, wherein at least one of the correcting codes comprises a Winograd code.

67. The method according to claim 64, wherein at least one of the correcting codes comprises a symmetric code.

68. The method according to claim 64, wherein at least one of the correcting codes comprises a Reed-Solomon code.

69. The method according to claim 64, wherein at least one of the correcting codes comprises an EVENODD code.

70. The method according to claim 64, wherein at least one of the correcting codes is a derivative of an EVENODD code.

71. The method according to claim 46, wherein when an element in the donor stripe fails during rebuilding at least a portion of recipient information from the recipient stripe on the selected element, the method further comprising:

terminating rebuilding at least a portion of recipient information from the recipient stripe on the selected element;

selecting a second donor stripe from the plurality of stripes when a difference between a minimum distance of the second donor stripe and a minimum distance of the second recipient stripe is greater or equal to 2;

selecting a donor element in the second donor stripe; and

rebuilding at least a portion of lost recipient information from the recipient stripe on the selected element in the second donor stripe.

72. The method according to claim 46, wherein when a spare element becomes available, the method further comprising assigning the spare element to a selected storage unit.

73. A data storage system, comprising;

an array of m storage units in which m is an integer, k stripes being stored across the array of m storage units in which k is an integer, each stripe comprising $n + r$ elements in which n is the number of data elements in the stripe and r is the number of redundant elements in the stripe, $m > n + r$, $jm = k(n + r)$, and j is an integer, each stripe forming a correcting code, the correcting code being at least one of an erasure correcting code having a minimum Hamming distance d and an error correcting code having a minimum Hamming distance d, and each respective element of a stripe being stored on a different storage unit; and

a system array controller selecting an element in a donor stripe when a difference between a minimum distance of the donor stripe and a minimum distance of a recipient stripe is greater or equal to 2 and when an element of the recipient stripe is lost, the donor stripe and the recipient stripe being from the k stripes, the selected element being stored on a storage unit having no elements of the recipient stripe; the system array controller increasing the minimum distance of the recipient stripe by rebuilding the lost element of the recipient stripe on the selected element of the donor stripe so that the recipient stripe can tolerate a loss of another element without loss of data.

74. The data storage system according to claim 73, wherein the minimum Hamming distance of the recipient stripe is $d > 2$ before the system array controller selects the element in the donor stripe.

75. The data storage system according to claim 73, wherein the system array controller indicates to the storage units storing the donor stripe that the selected element has been donated before the lost element of the recipient stripe is rebuilt on the selected element.

76. (canceled)

77. The data storage system according to claim 73, wherein the storage units comprise hard disk drives.

78. The data storage system according to claim 73, wherein the storage units comprise RAM storage devices.

79. The data storage system according to claim 73, wherein the system array controller selects the donor stripe further based on a minimal performance impact on the array.

80. The data storage system according to claim 73, wherein the system array controller selects the recipient information based on an improved performance of the array.

81. The data storage system according to claim 73, wherein the correcting code comprises a parity code.

82. The data storage system according to claim 73, wherein the correcting code comprises a Winograd code.

83. The data storage system according to claim 73, wherein the correcting code comprises a symmetric code.

84. The data storage system according to claim 73, wherein the correcting code comprises a Reed-Solomon code.

85. The data storage system according to claim 73, wherein the correcting code comprises an EVENODD code.

86. The data storage system according to claim 73, wherein the correcting code comprises a derivative of an EVENODD code.

87. The data storage system according to claim 73, wherein the array comprises redundancy based on a product of a plurality of correcting codes.

88. The data storage system according to claim 87, wherein at least one of the correcting codes comprises a parity code.

89. The data storage system according to claim 87, wherein at least one of the correcting codes comprises a Winograd code.

90. The data storage system according to claim 87, wherein at least one of the correcting codes comprises a symmetric code.

91. The data storage system according to claim 87, wherein at least one of the correcting codes comprises a Reed-Solomon code.

92. The data storage system according to claim 87, wherein at least one of the correcting codes comprises an EVENODD code.

93. The data storage system according to claim 87, wherein at least one of the correcting codes comprises a derivative of an EVENODD code.

94. The data storage system according to claim 73, wherein when an element in the donor stripe fails as the system array controller is rebuilding at least a portion of recipient information from the recipient stripe on the selected element, the system array controller terminates rebuilding the recipient information from the recipient stripe on the selected element, selects a second donor stripe from the plurality of stripes when a difference between a minimum distance of the second donor stripe and a minimum distance of the second recipient stripe is greater or equal to 2, selects a donor element in the second donor stripe, and rebuilds at least a portion of lost recipient information from the recipient stripe on the selected element in the second donor stripe.

95. The data storage system according to claim 73, wherein when a spare element becomes available, the system array controller assigns the spare element to a selected storage unit.

96. A data storage system, comprising:

an array of m storage units, k stripes being stored across the array of m storage units, each stripe comprising $n + r$ elements in which n is the number of data elements in the stripe and r is the number of redundant elements in the stripe, $m > n + r$, $jm = k(n + r)$, and j and k are integers, each stripe forming an erasure or error correcting code having a minimum Hamming distance d, and each respective element of a stripe being stored on a different storage unit; and

a system array controller selecting a recipient element subsequent to an element failure and selecting an element in a donor stripe **wherein** a failure tolerance of the array is increased following a rebuild operation so that the recipient stripe can tolerate a loss of another element without loss of data, the system array controller rebuilding a lost element of the recipient stripe on the selected element of the donor stripe.

97. The data storage system according to claim 96, wherein the minimum Hamming distance of the recipient stripe is $d > 2$ before the system array controller selects the element in the donor stripe.

98. The data storage system according to claim 96, wherein the minimum Hamming distance of the array is increased upon completion of rebuilding the lost element of the recipient stripe on the selected element of the donor stripe.

99. The data storage system according to claim 96, wherein system array controller selects the recipient element based on a failure pattern of the array.

100. The data storage system according to claim 96, wherein system array controller selects the donor element based on a predetermined target pattern.

101. The data storage system according to claim 96, wherein the system array controller indicates to the storage units storing the donor stripe that the selected element has been donated before the lost element of the recipient stripe is rebuilt on the selected element.

102. (canceled)

103. The data storage system according to claim 96, wherein the storage units comprise hard disk drives.

104. The data storage system according to claim 96, wherein the storage units comprise RAM storage devices.

105. The data storage system according to claim 96, wherein the erasure or error correcting code comprises a parity code.

106. The data storage system according to claim 96, wherein the erasure or error correcting code comprises a Winograd code.

107. The data storage system according to claim 96, wherein the erasure or error correcting code comprises a symmetric code.

108. The data storage system according to claim 96, wherein the erasure or error correcting code comprises a Reed-Solomon code.

109. The data storage system according to claim 96, wherein the erasure or error correcting code comprises an EVENODD code.

110. The data storage system according to claim 96, wherein the erasure or error correcting code comprises a derivative of an EVENODD code.

111. The data storage system according to claim 96, wherein the array of storage units comprises redundancy based on a product of a plurality of erasure or error correcting codes.

112. The data storage system according to claim 111, wherein at least one of the erasure or error correcting codes comprises a parity code.

113. The data storage system according to claim 111, wherein at least one of the erasure or error correcting codes comprises a Winograd code.

114. The data storage system according to claim 111, wherein at least one of the erasure or error correcting code comprises a symmetric code.

115. The data storage system according to claim 111, wherein at least one of the erasure or error correcting code comprises a Reed-Solomon code.

116. The data storage system according to claim 111, wherein at least one of the erasure or error correcting code comprises an EVENODD code.

117. The data storage system according to claim 111, wherein at least one of the erasure or error correcting code comprises a derivative of an EVENODD code.

118. A data storage system, comprising:

a plurality of arrays of storage units, each array having m storage units, k stripes being stored across each respective array of m storage units, each stripe comprising $n + r$ elements in which n is the number of data elements in the stripe and r is the number of redundant elements in the stripe, $m > n + r$, $jm = k(n + r)$, and j and k are integers, each stripe forming an error or erasure correcting code having a minimum Hamming distance $d = n + 1$, and each respective element of a stripe being stored on a different storage unit in the array; and

a system array controller selecting an element in a donor stripe when a difference between a minimum distance of the donor stripe and a minimum distance of a recipient stripe is greater or equal to 2, the selected element being stored on a storage unit having no elements of the recipient stripe, the system array controller rebuilding a lost element of the recipient stripe on the selected element.

119. The data storage system according to claim 118, wherein the donor stripe is stored on an array that is different from the array of the recipient stripe.

120. The data storage system according to claim 118, wherein the donor stripe is stored on the same array as the recipient stripe.

121. The data storage system according to claim 118, wherein the minimum Hamming distance of the recipient stripe is $d > 2$ before the step of selecting the element in the donor stripe.

122. The data storage system according to claim 118, wherein the system array controller indicates to the storage units storing the donor stripe that the selected element has been donated before the lost element of the recipient stripe is rebuilt on the selected element.

123. (canceled)

124. The data storage system according to claim 118, wherein the storage units comprise hard disk drives.

125. The data storage system according to claim 118, wherein the storage units comprise RAM storage devices.

126. The data storage system according to claim 118, wherein the donor stripe is further selected based on a minimal performance impact on the donor stripe.

127. The data storage system according to claim 118, wherein the selected element of the donor stripe is further selected based on a minimal performance impact on the storage system.

128. The data storage system according to claim 118, wherein the system array controller selects the recipient information based on an improved performance of the recipient stripe.

129. The data storage system according to claim 118, wherein the system array controller selects the recipient information based on an improved performance of the storage system.

130. The data storage system according to claim 118, wherein the erasure or error correcting code comprises a parity code.

131. The data storage system according to claim 118, wherein the erasure or error correcting code comprises a Winograd code.

132. The data storage system according to claim 118, wherein the erasure or error correcting code comprises a symmetric code.

133. The data storage system according to claim 118, wherein the erasure or error correcting code comprises a Reed-Solomon code.

134. The data storage system according to claim 118, wherein the erasure or error correcting code comprises an EVENODD code.

135. The data storage system according to claim 118, wherein the erasure or error correcting code comprises a derivative of an EVENODD code.

136. The data storage system according to claim 118, wherein the array comprises redundancy based on a product of a plurality of erasure or error correcting codes.

137. The data storage system according to claim 136, wherein at least one of the erasure or error correcting codes comprises a parity code.

138. The data storage system according to claim 136, wherein at least one of the erasure or error correcting codes comprises a Winograd code.

139. The data storage system according to claim 136, wherein at least one of the erasure or error correcting code comprises a symmetric code.

140. The data storage system according to claim 136, wherein at least one of the erasure or error correcting code comprises a Reed-Solomon code.

141. The data storage system according to claim 136, wherein at least one of the erasure or error correcting code comprises an EVENODD code.

142. The data storage system according to claim 136, wherein at least one of the erasure or error correcting code comprises a derivative of an EVENODD code.

143. The data storage system according to claim 118, wherein when an element in the donor stripe fails as the system array controller is rebuilding recipient information from the recipient stripe on the selected element, the system array controller terminates rebuilding recipient information from the recipient stripe on the selected element, selects a second donor

stripe from the plurality of stripes when a difference between a minimum distance of the second donor stripe and a minimum distance of the second recipient stripe is greater or equal to 2, selects a donor element in the second donor stripe, and rebuilds at least a portion of lost recipient information from the recipient stripe on the selected element in the second donor stripe.

144. The data storage system according to claim 118, wherein when a spare element becomes available, the system array controller assigns the spare element to a selected storage unit.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Guy J. Lamarre, P.E., whose telephone number is (571) 272-3826. The examiner can normally be reached on Monday to Friday from 9:30 AM to 6:00 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jacques Louis-Jacques, can be reached at (571) 272-6962. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

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/Guy J Lamarre/

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